ANALYSIS OF LANDSCAPE, WEATHER AND MOSQUITO VECTOR ECOLOGY FOR PREDICTING ARBOVIRUS DISEASE SPREAD

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Objectives of the study

- Pantanal National Park is a protected wetland with restricted human and domestic animal presence
- Determine environmental parameters that affect vector habitat & disease spread
- Monitor arbovirus disease in the wildlife

- Describe the mosquito vector ecology
- Determine relationships between environmental factors and populations of specific mosquito species
- Determine presence of arboviruses and document history of disease exposure in susceptible hosts
Location of Study Area in Pantanal, Brazil
Digital Elevation Model of Pantanal Wetland
Specific landscape characteristics in each collection area (point 1)
Point 3- Hotel
Points 4 and 5
Arboviruses in the Americas is associated with animal and human diseases

- **Togaviridae**
  Mayaro, VEEV, EEEV, WEEV

- **Flaviviridae**
  CACI, DENV, ROCV, SLE, YFV, Ilheus, WNV

- **Bunyaviridae**
  OROV, LAC
DIPTERA
There are over 2500 different species of mosquitoes throughout the world.
## Vectors of viral diseases

<table>
<thead>
<tr>
<th>Virus / Mosquitos</th>
<th>Aedes</th>
<th>Psorophora</th>
<th>Culex</th>
<th>Haemagogus</th>
<th>Sabethes</th>
<th>Anopheles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dengue (DEN)</td>
<td>+++</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Febre Amarela (YF)</td>
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<td>Encefalite de São Luís (ESL)</td>
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<tr>
<td>Encefalite Equína Oeste (EEO)</td>
<td>+</td>
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<td>+++</td>
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<td>Encefalite Equína Leste (EEL)</td>
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<tr>
<td>Encefalite Equína Venezuelana (EEV)</td>
<td>+</td>
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<tr>
<td>Encefalite Rocio (ROC)</td>
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<td>Guamá (GUA)</td>
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<td>Ilhéus (ILH)</td>
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<td>+++</td>
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<td>++</td>
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<tr>
<td>Mayaro (MAY)</td>
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<td>Melao (MEL)</td>
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<td>Oropouche (ORO)</td>
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<td>Serra do Navio (SDN)</td>
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<td>Tacaiuma (TCM)</td>
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<td>+++</td>
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</table>
Pantanal, number of mosquitos/trap/night (one year summary-2010)

Specimens

- Anopheles evansae (220)
- Culex nigripalpus (110)
- Culex sp (60)
- Anopheles matogrossensis (12)
- Ochlerotatus fulvus (11)
- Psorophora albigna (6)
- Anopheles triannulatus (3)
- Mansonina humeralis (3)
- Mansonina titillans (3)
- Ochlerotatus scapularis (2)
- Anopheles albitarsis (1)
- Anopheles oswaldoi (1)
- Coquillettidia shannoni (1)
**Anopheles sp.**
In Pantanal may be vectors for Malaria (Xavier and Rebello, 1999): *An. evansae*, *An. matogrossensis*, *An. albitaris*, *An. oswaldoi*

**Culex sp.**
WNV, SLEV, JEV
the second most abundant species found in Pantanal is related to the transmission of SLEV (*Culex nigripalpus*)

Source: [http://www.fiocruz.br/~ccs/arquivosite/estetica/malaria.htm](http://www.fiocruz.br/~ccs/arquivosite/estetica/malaria.htm)
West Nile Virus Life Cycle
Coquillettidia sp.
Related to the transmission of arboviruses; OROV
*(Coquillettidia shannoni)*

Psorophora sp.
Related to the transmission of equine encephalitis; ILHV and WEEV
*(Psorophora albignau)*

Mosquito traps: CDC-CO2 and human bate
## Summary Statistics for total abundance, AN & CX by location

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>Std Dev.</th>
<th>3</th>
<th>Std Dev.</th>
<th>4</th>
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<td><strong>Total</strong></td>
<td>258.7</td>
<td>118.2</td>
<td>117.3</td>
<td>94.8</td>
<td>214.5</td>
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<td>341.0</td>
<td>77.1</td>
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<td><strong>AN</strong></td>
<td>30.9</td>
<td>19.4</td>
<td>36.8</td>
<td>38.9</td>
<td>51.3</td>
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<td><strong>CX</strong></td>
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<td>60.4</td>
<td>42.5</td>
<td>44.8</td>
<td>100.7</td>
<td>159.7</td>
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<td>102.7</td>
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<td>AN</td>
<td>CX</td>
<td>TOTAL M</td>
<td>AN</td>
<td>CX</td>
<td></td>
<td></td>
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<td>January</td>
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<td>7.5</td>
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<td>290.1</td>
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<td>290.1</td>
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<td>July</td>
<td>142.6</td>
<td>45.4</td>
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<td>September</td>
<td>114.3</td>
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<td>November</td>
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### Average Proportions for AN and CX by month and location

<table>
<thead>
<tr>
<th></th>
<th>AN</th>
<th></th>
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<th></th>
<th></th>
<th>CX</th>
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<td>5</td>
<td>all</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>all</td>
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<tr>
<td>January</td>
<td>0.07</td>
<td>0.01</td>
<td>0.01</td>
<td>0.04</td>
<td><strong>0.04</strong></td>
<td>0.03</td>
<td>0.22</td>
<td>0.54</td>
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<td>0.07</td>
<td>0.27</td>
<td><strong>0.41</strong></td>
<td><strong>0.67</strong></td>
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<td>0.78</td>
<td>0.50</td>
<td>0.44</td>
<td>0.30</td>
<td><strong>0.51</strong></td>
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<td>May</td>
<td><strong>0.43</strong></td>
<td><strong>0.61</strong></td>
<td>0.34</td>
<td><strong>0.49</strong></td>
<td><strong>0.41</strong></td>
<td>0.51</td>
<td>0.14</td>
<td>0.31</td>
<td>0.37</td>
<td>0.33</td>
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<td>July</td>
<td>0.22</td>
<td>0.31</td>
<td>0.42</td>
<td><strong>0.32</strong></td>
<td><strong>0.41</strong></td>
<td>0.59</td>
<td>0.34</td>
<td>0.33</td>
<td></td>
<td><strong>0.41</strong></td>
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<tr>
<td>September</td>
<td>0.01</td>
<td>0.03</td>
<td>0.04</td>
<td>0.32</td>
<td><strong>0.06</strong></td>
<td>0.89</td>
<td>0.80</td>
<td>0.78</td>
<td>0.09</td>
<td><strong>0.74</strong></td>
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<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
<td>0.07</td>
<td><strong>0.03</strong></td>
<td>0.85</td>
<td>0.65</td>
<td>0.46</td>
<td>0.21</td>
<td><strong>0.50</strong></td>
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<td>TOTALS</td>
<td>0.12</td>
<td>0.32</td>
<td>0.24</td>
<td>0.53</td>
<td><strong>0.31</strong></td>
<td>0.64</td>
<td>0.36</td>
<td>0.47</td>
<td>0.30</td>
<td><strong>0.45</strong></td>
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</tbody>
</table>
Cuiabá
Brazil

![Graph of High/Low Temperature and Rainfall](image)
Field collected water temperatures (C) 2009-2010

(pools / inside tree holes)

January: 30C/ 23C
March: 26C/23C
May: 27C/23C
July: 24C/22C
September: 29C/21C
November: 29C/24C
IMAGE PROCESSING & METHODOLOGY

LANDSAT Images

BT
Brightness Temperature

Radiance / Reflectance

Atmospheric Corrections

LST
Land Surface Temp

NDVI
Vegetation Index

NDMI
Moisture Index

NDWI
Water Index

Mosquito Sampling Points

Correlation of Environmental Parameters with Mosquitos
AN = Anopheles
CX = Culex

Proximity to Water Bodies
Flooded Area
Shallow Water
Deep Water
Normalized Difference Moisture Index (also called Infrared Index) uses near infrared and mid-infrared bands, and is very sensitive to changes in plant biomass and water stress (Hardisky et al., 1983; Wilson et al., 2002); very useful in wetland studies:

$$NDMI = \frac{NIR_{TM4} - MIR_{TM5}}{NIR_{TM4} + MIR_{TM5}}$$

Normalized Difference Water Index (NDMI) is useful for delineating open water (McFeeters, 1996):

$$NDWI = \frac{GREEN_{TM2} - NIR_{TM4}}{GREEN_{TM2} + NIR_{TM4}}$$
$T_B$ are retrieved by converting spectral radiance to at top of the atmosphere (TOA) brightness temperature using the formula:

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)}$$

$T_B = \text{effective at satellite brightness temperature (K)}$

$L_\lambda = \text{spectral reflectance}$

$K_1$ and $K_2 = \text{thermal band calibration constants (units respectively in Wm}^{-2}\text{sr}^{-1}\mu\text{m}^{-1} \text{and Kelvin)}$
For retrieval of Land Surface Temperature (LST) atmospheric profiles of temperature and water vapor measured concurrently with satellite acquisition are necessary as inputs of a radiative transfer code, together with surface-emissivity data. A Web-based ACT (http://atmcorr.gsfc.nasa.gov) was used to obtain such parameters.

\[
LST = \frac{L_{\text{sen}} - L^\uparrow}{\varepsilon \tau} - \frac{1 - \varepsilon}{\varepsilon} L^\downarrow
\]

LST = surface temperature  
\(L_{\text{sen}}\) = at sensor radiance  
\(L^\uparrow\) = upwelling radiance  
\(L^\downarrow\) = downwelling radiance  
\(\tau\) = atmospheric transmittance  
\(\varepsilon\) = emissivity of surface material

Coll et al. (2010) note that small overestimation between 0.15 and 0.3 K in the derived LST are possible.
**Culex sp** proportion is highest in March and September.

**Anopheles sp** peak in March and May and drop in September.

<table>
<thead>
<tr>
<th>Months/Locations</th>
<th>1</th>
<th>3</th>
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<tbody>
<tr>
<td>January</td>
<td>NDVI HIGH HOT MOIST</td>
<td>NDVI HIGH HOT MOIST</td>
<td>NDVI HIGH HOT MOIST</td>
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<tr>
<td>March</td>
<td>NDVI LOW HOT MOIST</td>
<td>NDVI MOD TEMP MOD MOIST</td>
<td>NDVI HIGH TEMP MOD MOIST</td>
<td>NDVI HIGH TEMP MOD MOIST</td>
</tr>
<tr>
<td>May</td>
<td>COLD/DRY</td>
<td>COLD/DRY</td>
<td>COLD/MOD DRY</td>
<td>COLD/MOD DRY</td>
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<td>July</td>
<td>COLD NDVI LOW DRY</td>
<td>COLD NDVI LOW DRY</td>
<td>COLD NDVI LOW DRY</td>
<td>COLD NDVI LOW DRY</td>
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<tr>
<td>September</td>
<td>HOT/DRY</td>
<td>HOT/DRY</td>
<td>HOT/DRY</td>
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<td>November</td>
<td>HOT NDVI HIGH MOIST</td>
<td>HOT NDVI HIGH MOIST</td>
<td>HOT NDVI HIGH MOIST</td>
<td>HOT NDVI HIGH MOIST</td>
</tr>
</tbody>
</table>

Migration of birds to the Northern Hemisphere.

Migration of birds from Northern Hemisphere.
Conclusions

- High incidence of Anopheles in colder/higher NDVI habitats. Peaks from March to May. Does not survive dry season (June-September)
- Incidence for Culex sp peaks twice a year: March and September; and survives dry season
- West Nile virus could be transmitted in March (from local birds to migratory birds) and September (from migratory birds to local birds) perpetuating transmission of WNV in the whole Continent
Conclusions

- Satellite time series with good temporal & spatial resolution are essential for monitoring environmental factors favoring vector habitats and disease spread.
- Limited access to high quality satellite data are due to cloud cover and problems with older satellite systems (LANDSAT 7, ASTER, ALOS)
- Time series of temperature, vegetation, soil moisture and open water bodies are useful for characterizing and monitoring the ecosystem of mosquito disease vectors
Acknowledgments

- Instituto Oswaldo Cruz. Diptera Laboratory, Rio de Janeiro, Brazil
- Panthera Inc, NY, USA
- Mount Sinai School of Medicine, NY, USA
- Boston University Center for Remote Sensing
- Tufts University, MA, USA
- Massachusetts Institute of Technology, MA, USA